PASJ: Publ. Astron. Soc. Japan , 1–??,

The 2005 July Superoutburst of the Dwarf Nova 2QZ J021927.9-304545: the SU UMa nature confirmed

Akira IMADA, Taichi KATO
[1] *Department of Astronomy, Faculty of Science, Kyoto University, Sakyo-ku, Kyoto 606-8502*
a_imada@kusastro.kyoto-u.ac.jp
L.A.G. MONARD
Bronberg Observatory, CBA Pretoria, PO Box 11426, Tiegerpoort 0056, South Africa
Alon RETTER
Department of Astronomy & Astrophysics, Penn State University,
525 Davey Lab, University Park, PA 16802-6305, USA
Alex LIU
Norcape Observatory, PO Box 300, Exmouth WA 6707, Australia
Daisaku NOGAMI
Hida Observatory, Kyoto University, Kamitakara, Gifu 506-1314

(Received ; accepted)

Abstract

We report on time-resolved photometry of the 2005 July superoutburst of the dwarf nova, 2QZ J021927.9-304545. The resultant light curves showed conspicuous superhumps with a period of 0.081113(19) days, confirming the SU UMa nature of the object. Although we missed the maximum phase of the outburst, the amplitude of the superoutburst well exceeded 5 mag. This value is slightly larger than that of typical SU UMa-type dwarf novae. The superhump period decreased as time elapsed, as can be seen in most SU UMa-type dwarf novae. Based on the archive of ASAS-3, the recurrence time of a superoutburst of the variable turned out to be about 400 days. This value is typical of well known SU UMa stars. The distance to this system was roughly estimated as 370(+20, -60) pc using an empirical relation.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (2QZ J021927.9-304545) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

Cataclysmic variables are close binany systems that consist of a white dwarf primary and a late-type secondary star. The secondary star fills its Roche-lobe, leading to mass transfer via the inner Lagragian point (L_1), forming an accretion disk around the white dwarf (for a review, see e.g., Warner 1995; Hellier 2001). Dwarf novae are a subclass of cataclysmic variables, further subdivided into three types: U Gem stars, Z Cam stars, and SU UMa stars, based on their outburst properties (for a review, Osaki 1996; Kato et al. 2004). SU UMa-type dwarf novae, which have orbital periods below 2 hours in most cases, exhibit two types of outburst: normal outbursts whose duration is a few days and superoutbursts which continue for about 2 weeks. Superoutbursts are always accompanied by ~ 0.2 mag modulations called superhump. It is believed that a tidally deformed eccentric accretion disk gives rise to phase-dependent tidal dissipation, which is observed as superhumps (Whitehurst 1988; Osaki 1989). Optical photometry for SU UMa-type dwarf novae during superoutbursts is one of the best ways to decipher the dynamics of the accretion disk.

2QZ J021927.9-304545 is catalogued in 2dF QSO Redshift Survey (2QZ) (Boyle et al. 2000). A possible 2MASS counterpart has $J = 16.391(0.118)$, $H = 15.671(0.142)$, and $K = 15.359(0.202)$, respectively (for 2MASS compilation of dwarf novae, see Hoard et al. 2002; Imada et al. 2005). The object is identified with USNO B1.0 0592-0024305 ($B1 = 18.72$, $R1 = 18.49$, $R2 = 17.62$, $I2 = 18.02$). Long-term photometric monitoring of this object was performed by the All Sky Automated Survey (ASAS, Pojmanski 2002). ASAS-3 monitoring over the past few years has provided some evidence that the star is a possible candidate for an SU UMa-type dwarf nova. To test the SU UMa nature of the system, we have continuously monitored the object at CBA Pretoria since 2005 January. As a consequence, we detected an outburst on 2005 July 2 reaching a magnitude of about 11.9 in R_c. However, bad weather prevented us from time-resolved observations during the first day of discovery. As for the ASAS-3 survey, the variable was invisible on 2005 June 22 with the magnitude below the detection limit of the ASAS-3, the object got brightened up to V $\sim$ 12.5 mag on 2005 July 3. After that we performed time-resolved CCD observations. Conspicuous feature of superhumps was detected, so that we confirmed the SU UMa nature of the object. Quiescent photometry of the object was carried out at CBA Pretoria, yielding 18.2 in R_c (see e.g., [vsnet-alert 8521])[1].

[1] http://ooruri.kusastro.kyoto-u.ac.jp/pipermail/vsnet-

Table 1. Log of Observations.

HJD(start)*	HJD(end)	N†	Exp(s)‡	Observer§
3555.5776	3555.6681	498	15	BM
3556.5206	3556.6717	796	15	BM
3557.5063	3557.6535	808	15	BM
3558.5113	3558.6767	910	15	BM
3559.5070	3559.6761	932	15	BM
3561.5359	3561.6708	381	30	BM
3562.5185	3562.6683	380	30	BM
3563.4719	3563.6730	570	30	BM
3564.5204	3564.6707	426	30	BM
3565.3170	3565.4093	64	30	AL
3565.4987	3565.6409	394	30	BM
3566.5356	3566.6626	350	30	BM
3567.5472	3567.6694	345	30	BM

* HJD - 2450000. † Number of frames.
‡ Exposure times.
§ BM: L.A.G. Monard, 32-cm telescope, SBIG ST-7XME Pretoria, South Africa.
AL: Alex Liu, 30-cm telescope, SBIG ST-7e Exmouth, Australia.

In the paper, we report on photometric results during the 2005 July superoutburst of 2QZ J021927.9-304545, as well as long-term observations of the object (hereafter aliased 2QZ 0219).

2. Observations

Time-resolved CCD observations were carried out at two sites of the VSNET Collaboration team (see Kato et al. 2004). A journal of observations is summarized in table 1. Although we did not use any filters, the obtained data were close to those of R_c−system. The exposure times were 15 and 30 sec, with a read-out time of a few seconds. All frames were processed using AIP4WIN, and magnitudes were derived by aperture photometry. As the comparison star, we used GSC7007.1900, whose constancy was checked against several field stars. The precision of individual data points was estimated to be better than 0.03 mag. The calibrated magnitude for each site was adjusted to ASAS-3 data of the object.

Heliocentric correction was made for each data set before the following analysis.

3. Results

3.1. *light curve*

The overall light curve is represented in figure 1, in which the ASAS-3 observations are plotted by open squares as well. At onset of our observation, 2QZ 0219 brightened up to 12.4 mag. After that, the magnitude slightly declined at a rate of 0.12 mag d^{-1}, which is a typical value of SU UMa stars. On HJD 2453565, 10 days after the epoch of our first observation, the object plummeted

alert/2005-July/000140.html

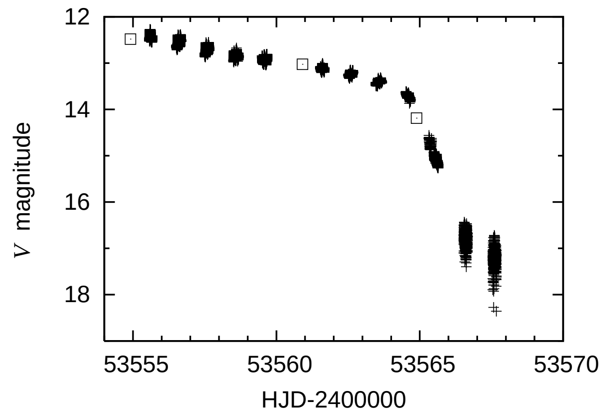

Fig. 1. The entire light curve of the 2005 July superoutburst. The abscissa and the ordinate denote HJD−2400000 and V magnitude, respectively. The open squares indicate the ASAS-3 photometry for which the typical error is within the size of the square. The duration of the plateau stage is at least 10 days, during which the object gradually fades at a rate of about 0.12 mag d^{-1}.

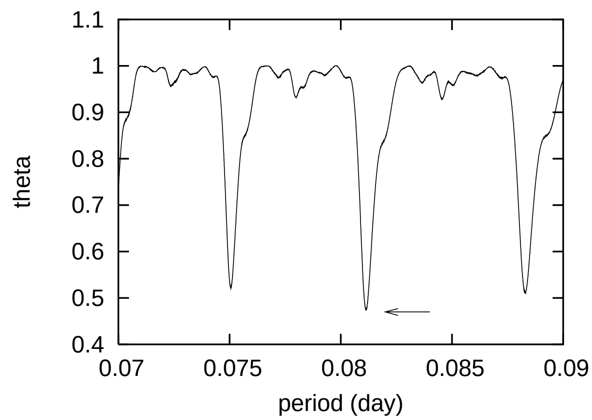

Fig. 2. Theta diagram obtained by operating the PDM method to the data during the plateau stage after prewhitening. The best estimated period of superhumps is 0.081179(7) days.

at a rate of 1.54 mag d^{-1}, after which 2QZ 0219 faded down to 17 mag. No rebrightening feature was detected during our run. However, the presence of a rebrightening after HJD 2453567 can not be ruled out.

3.2. *superhumps*

Conspicuous superhumps were detected during the whole run. After subtracting the linear declining trend, we performed a period analysis using the phase dispersion minimization method (PDM) (Stellingwerf 1978). We determined 0.081179 days as the best estimated period of the superhump. Figure 2 shows the theta diagram for the plateau stage. The error of the period was estimated using the Lafler-Kinman class of methods, as applied by Fernie (1989).

Figure 3 shows a phase-averaged superhump profile dur-

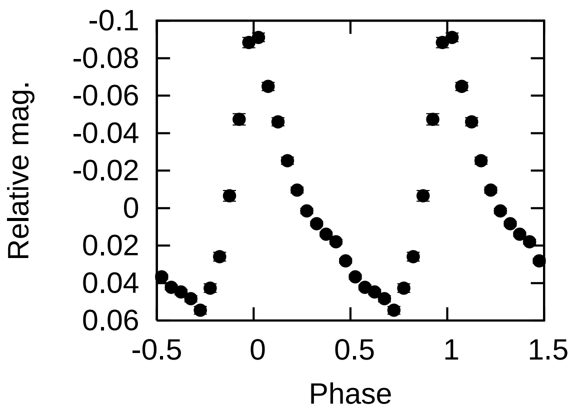

Fig. 3. Phase-averaged superhumps during the plateau stage foleded by 0.081179 days. A rapid rise and slow decline are characteristic of superhumps.

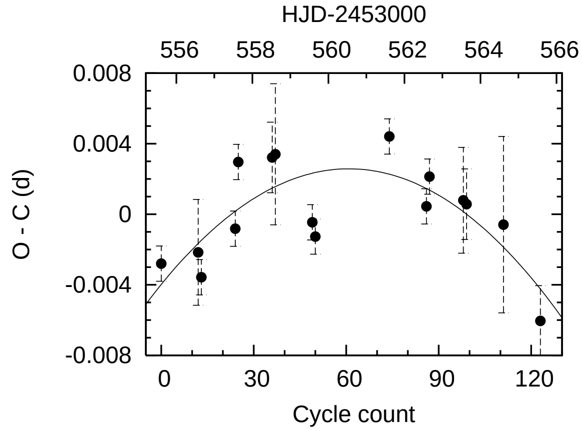

Fig. 5. $O-C$ diagram of the superhump maximum timings. The abscissa and ordinate mean the cycle count and $O-C$, respectively. A linear regression (C) and the best quadratic fit are given in equation (1) and (2), respectively. Note that the superhump period decreased with time.

Table 2. Timing of superhump maxima.

E*	HJD†	err‡
0	3555.5997	0.001
12	3556.5737	0.003
13	3556.6534	0.001
24	3557.5484	0.001
25	3557.6333	0.001
36	3558.5258	0.002
37	3558.6071	0.004
49	3559.5766	0.001
50	3559.6569	0.001
74	3561.6093	0.001
86	3562.5787	0.001
87	3562.6615	0.001
98	3563.5524	0.003
99	3563.6333	0.002
111	3564.6055	0.005
123	3565.5734	0.002

* Cycle count.
† HJD-2450000
‡ In the unit of day.

ing the plateau stage folded by 0.081179(7) days after subtracting a nightly decline trend. As can be seen in figure 3, a rapid-rise and slow-decline, typical of superhump profile among SU UMa stars, are remarkable. Daily-averaged superhump profiles, folded by 0.081179(7) days, are depicted in figure 4. The shape of the superhump variation was almost maintained with an amplitude of ∼0.2 mag except the last two days of our run.

3.3. superhump period change

We further examined the timing of the superhump maxima for the whole superoutburst. The estimated superhump maxima are listed in table 2. The typical error of each maximum is of the order of 0.002 days. A linear regression for the values listed in table 2 yielded the following equation,

$$HJD(max) = 0.081113(19) \times E + 53555.6025(13), \quad (1)$$

where the values in the parentheses denote the errors. By fitting the deviation of the observed timings from the above calculation, we derived the best fitted quadratic equation as follows:

$$O-C = -3.98(1.35) \times 10^{-3} + 2.15(0.55) \times 10^{-4}E - 1.77(0.44) \times 10^{-6}E^2. \quad (2)$$

This equation indicates $P_{\rm dot} = \dot{P}/P = -4.4(1.1)\times 10^{-5}$, which is an ordinary value for SU UMa stars (Uemura et al. 2005; Olech et al. 2005). Figure 5 shows the obtained $O-C$ diagram, as well as the best fitted quadratic curve.

4. Discussion

4.1. recorded outbursts

Thanks to the ASAS-3 survey (Pojmanski 2002), we can investigate the recorded outbursts over the past few years. The long-term photometric behavior of 2QZ 0219 by ASAS-3 is demonstrated in figure 6. From these data we judged the outburst type for each outburst, and summarized it in table 3. Suspected superoutbursts except the present one have been recorded on 2001 Sep. 15, 2002 Sep. 21, and 2003 Sep. 10, so that we can roughly estimate the supercycle of the object as follows:

$$T_{rec} = (3554.91624 - 2167.74163)/(3+N), \quad (3)$$

where N denotes the number of overlooked superoutbursts. With a little algebra, we determine T_{rec} = 346 – 462 days. The obtained supercycle length is a typical value of SU UMa-type dwarf novae (Kato et al. 2003; Nogami et al. 1997).

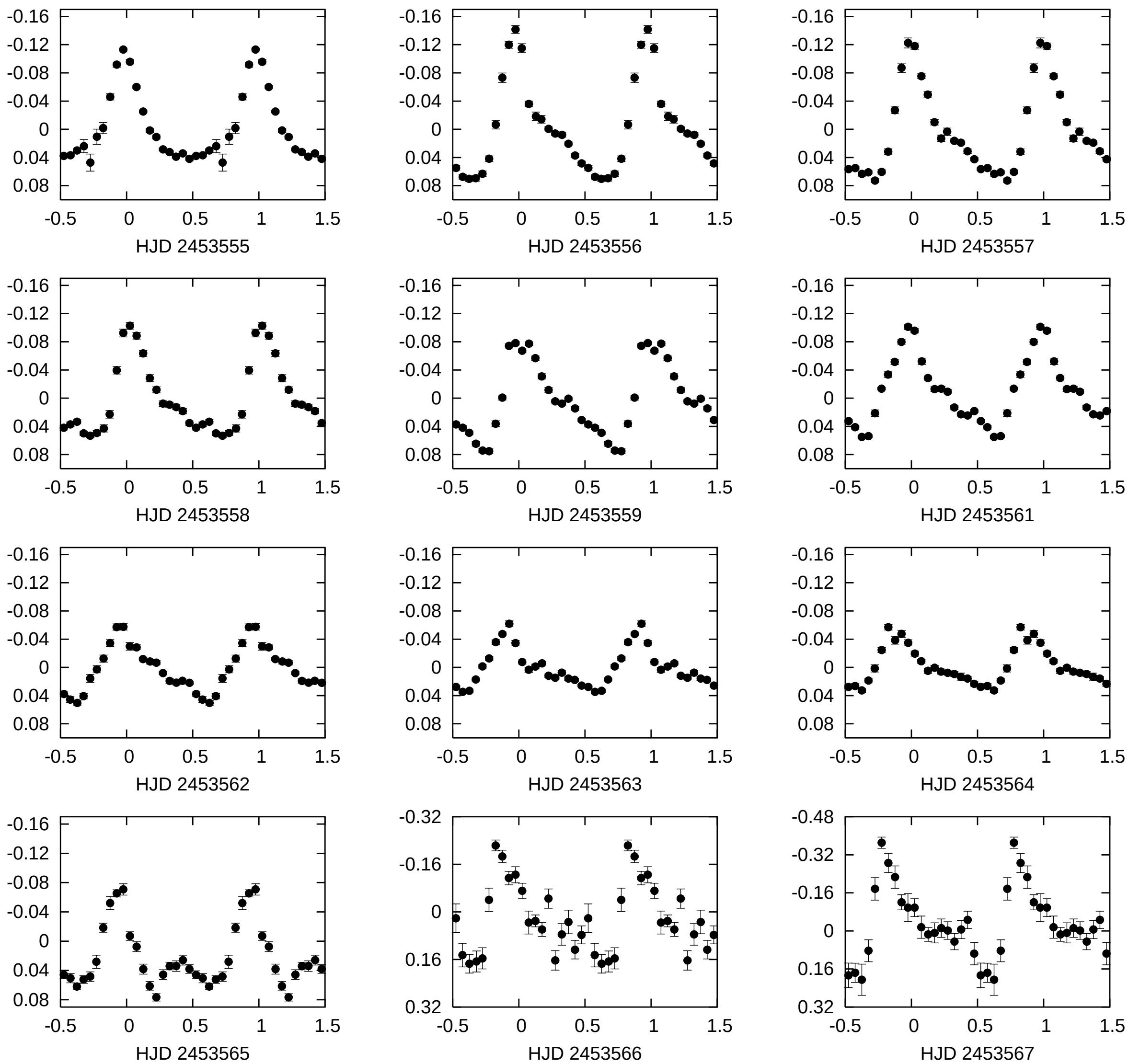

Fig. 4. Daily averaged profile of the data folded by the 0.081179-d superhump period after subtracting the linear decline trend. The vertical and the horizontal axis denote the relative magnitude and phase, respectively. The epoch of phase is set on HJD 2455355.6025. The vertical axis is different for the last 2 runs.

4.2. distance

If the orbital period of the system and the magnitude of its normal outburst are known, one can roughly estimate the distance to the object by an empirical relation for dwarf novae with a low-mid inclination. According to Warner (1987), the absolute magnitude of dwarf novae is given as a function of its orbital period,

$$M_V = 5.64(13) - 0.259(24) \times P, \tag{4}$$

where M_V and P mean the absolute magnitude of dwarf novae in V at the maximum of the normal outburst, and the orbital period in the unit of hours, respectively. Unfortunately, we have no information about the orbital period of 2QZ 0219. Instead, we settle for using the obtained superhump period as P. This prescription is fairly valid because there is enough evidence that the difference between the superhump period and orbital period is only a few percent. In addition, the absence of an eclipse during the whole superoutburst indicate that 2QZ 0219 is not a high inclination system. Hence, we can safely use the above equation in order to estimate a distance to the object. With a little algebra, a plausible distance to 2QZ 0219 lies in 370(+20, -60) pc. This distance should be checked by other methods in future.

4.3. superhump period change

High speed CCD photometry has revealed that SU UMa-type dwarf novae show changes of the superhump period during the superoutburst. Most SU UMa-type dwarf novae show a decrease in their superhump periods as the superoutburst proceeds, presumably due to the shrinkage of the disk radius, or to a natural consequence of mass

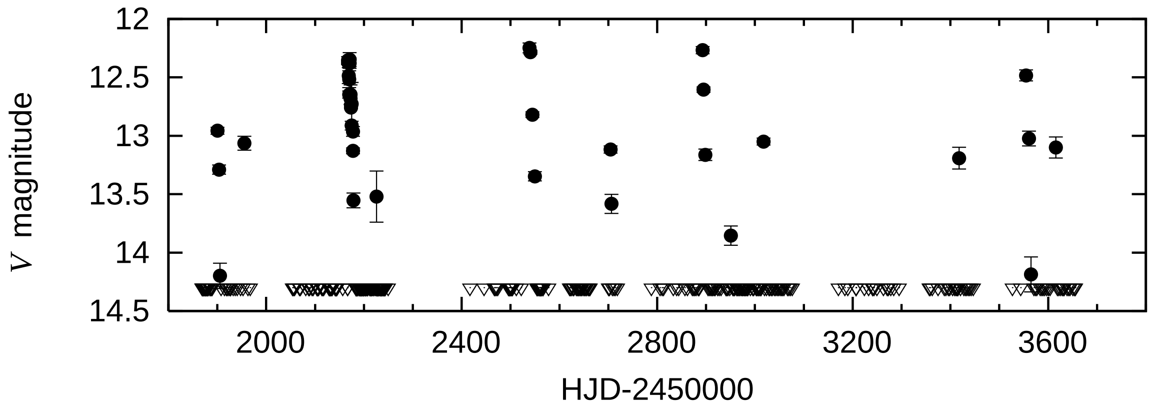

Fig. 6. The long-term light curve of 2QZ 0219 taken from the ASAS-3. The horizontal axis shows HJD-2450000, and the vertical axis shows V magnitude. Filled circles and bottom triangles mean positive and negative observations, respectively. $V = 14.3$ is the limiting magnitude.

Table 3. Recorded outbursts

HJD (1)	Mag (2)	$T_{\min}$ (3)	$T_{\max}$ (4)	N (5)	Type (6)
1900.54153	12.96	5	18	3	S:
1955.53592	13.06	1	10	1	N
2167.74163	12.37	10	17	7	S
2225.62825	13.52	1	9	1	N
2538.78054	12.25	11	32	4	S
2704.50660	13.12	2	6	2	N
2892.83091	12.27	6	18	3	S
2950.66662	13.86	1	6	1	N
3017.66734	13.05	1	7	1	N
3417.57925	13.19	1	5	1	N
3554.91624	12.48	10	27	3	S*
3615.88048	13.10	1	15	1	N

Columns. − (1) HJD−2450000; (2) Maximum magnitude detected by ASAS-3; (3) Minimum outbursting duration in the unit of day; (4) Maximum outbursting duration in the unit of day; (5) Number of frames; (6) Type of outbursts. N: normal outburst; S: superoutburst
* This work.

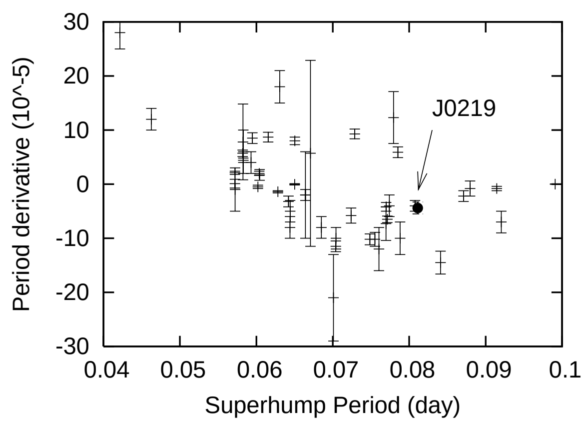

Fig. 7. $P_{\rm sh}-\dot{P}$ diagram of $O-C$ variation explored SU UMa stars. The location of 2QZ 0219 is designated as a filled circle. The data were originally taken from Imada et al. (2005).

depletion from the disk (Osaki 1985). Recently, it has turned out that several SU UMa-type dwarf novae including WZ Sge-type stars increase the superhump period with time[2]. Figure 7 represents period − $P_{\rm dot}$ diagram for SU UMa-type stars. As for the cause of increasing superhump period, Uemura et al. (2005) has given an insightful suggestion that the radius of the accretion disk at the outburst maximum is related to an increase or decrease of the superhump period. If the accretion disk is spread out well beyond the 3:1 resonance radius, where an eccentric mode sets in, the eccentric mode can propagate beyond the 3:1 resonance radius because there exists plenty mass in the outer region of the accretion disk during the superoutburst[3]. If the argument by Uemura et al. (2005) is correct, we can naturally explain why the increasing period of superhumps is *only* seen among WZ Sge-type stars and SU UMa stars with large amplitudes.

In the case of 2QZ 0219, taking into account the results of negative $P_{\rm dot}$ derivative and the above mentioned suggestion by Uemura et al. (2005), the radius of the accretion disk was not so large at the superoutburst maximum, at most, as much as the 3:1 resonance radius. Thus, the superhump period variation for 2QZ 0219 behaves as the "textbook" SU UMa-type dwarf novae. In order to test the validity of Uemura's implication, hydrodynamic simulation should be performed.

[2] Recently, V1028 Cyg (Baba et al. 2000) and TT Boo (Olech et al. 2004) showed both increasing and decreasing superhump period. Similar behavior was also observed in V1974 Cyg (Retter et al. 1997), although the object is classified as a permanent superhump system .

[3] WZ Sge stars and large-amplitude SU UMa stars meet this condition.

5. Summary

The present photometric observations of 2QZ 0219 allowed us to confirm a new member of SU UMa-type dwarf novae by detecting superhumps. The best estimated superhumps period of J0219 was 0.081113(19) days = 116.8 min, placing 2QZ 0219 near the lower edge of the period gap. In conjunction with our observations and the ASAS-3 archival data, the plateau stage of the superoutburst lasted at most 20 days. The amplitude of the superoutburst exceeded 5 mag, slightly larger than ordinary SU UMa-type dwarf novae but within the normal range. An estimation of the recurrence time of the superoutburst yielded $\sim 346 - 462$ days. We can roughly determine the distance to 2QZ 0219 to be 370(+20, -60) pc. The resultant $O-C$ diagram, together with the above results, led us to the conclusion that 2QZ 0219 is a new member of a prototypical SU UMa-type dwarf nova.

We are grateful to many VSNET observers who have reported vital observations. We would also express our gratitude to G. Pojmanski for providing invaluable data of ASAS-3 observations. This work is supported by a Grant-in-Aid for the 21st Century COE "Center for Diversity and Universality in Physics" from the Ministry of Education, Culture, Sports, Science and Technology (MEXT). This work is partly supported by a grant-in aid from the Ministry of Education, Culture, Sports, Science and Technology (No. 16340057, 17740105).

References

Baba, H., Kato, T., Nogami, D., Hirata, R., Matsumoto, K., & Sadakane, K. 2000, PASJ, 52, 429
Boyle, B. J., Shanks, T., Croom, S. M., Smith, R. J., Miller, L., Loaring, N., & Heymans, C. 2000, MNRAS, 317, 1014
Fernie, J. D. 1989, PASP, 101, 225
Hellier, C. 2001, Cataclysmic Variable Stars: how and why they vary (Berlin: Springer-Verlag)
Hoard, D. W., Wachter, S., Clark, L. L., & Bowers, T. P. 2002, ApJ, 565, 511
Imada, A., et al. 2005, PASJ, 57, 193
Imada, A., et al. 2005, astro-ph/0510764
Kato, T., Nogami, D., Moilanen, M., & Yamaoka, H. 2003, PASJ, 55, 989
Kato, T., Uemura, M., Ishioka, R., Nogami, D., Kunjaya, C., Baba, H., & Yamaoka, H. 2004, PASJ, 56S, 1
Nogami, D., Masuda, S., & Kato, T. 1997, PASP, 109, 1114
Olech, A., Cook, L. M., Złoczewski, K., Mularczyk, K., Kędzierski, P., Udalski, A., & Wisniewski, M. 2004, Acta Astron., 54, 2330
Olech, A., Złoczewski, K., Cook, L. M., Mularczyk, K., Kędzierski, P., & Wisniewski, M. 2005, Acta Astron., 55, 237
Osaki, Y. 1985, A&A, 144, 369
Osaki, Y. 1989, PASJ, 41, 1005
Osaki, Y. 1996, PASP, 108, 39
Pojmanski, G. 2002, Acta Astron., 52, 397
Retter, A., Leibowitz, E. M., & Ofek, E. O. 1997, MNRAS, 286, 745
Stellingwerf, R. F. 1978, ApJ, 224, 953
Uemura, M., et al. 2005, A&A, 432, 261
Warner, B. 1987, MNRAS, 227, 23
Warner, B. 1995, Cataclysmic Variable Stars (Cambridge: Cambridge University Press)
Whitehurst, R. 1988, MNRAS, 232, 35